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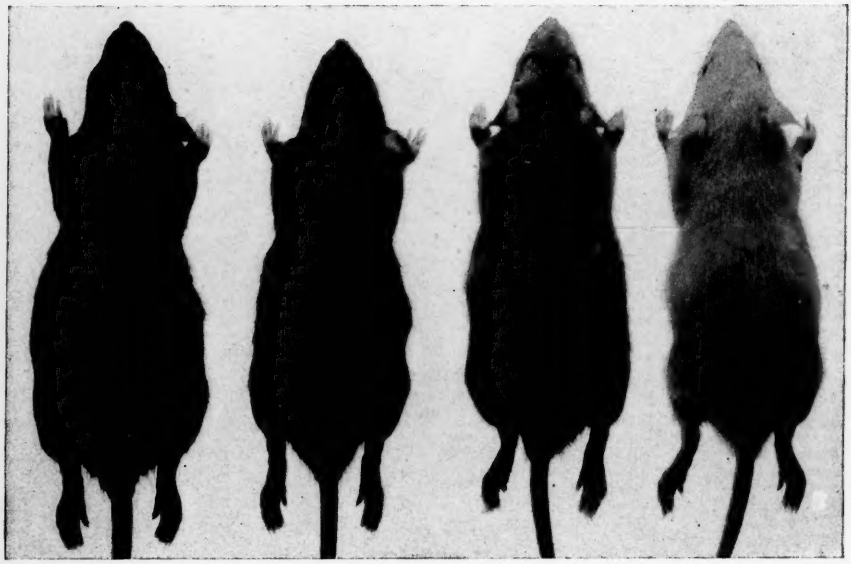

DOUBLE DILUTION
(SEE PAGE 344)

Pineapple Chimeras

Human Lobster-Claw

Sesame Genetics

Familial Single-Handed Hexadactyly

VOLUME 38 NOVEMBER, 1947 NUMBER 11

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The JOURNAL OF HEREDITY is published monthly by the AMERICAN GENETIC ASSOCIATION at 32nd Street and Elm Avenue, Baltimore, Md., and 1507 M St., N. W., Washington, D. C. Address all communications regarding editorial matters to 1507 M St., N. W., Washington, D. C. Communications regarding the business management of THE JOURNAL OF HEREDITY may be addressed to the publication office, 32nd Street and Elm Avenue, Baltimore, Md., or to 1507 M St., N. W., Washington 5, D. C. Entered as second-class matter February 24, 1923, at the postoffice at Baltimore, Maryland. Acceptance for mailing at the special rate of postage provided for in section 1103. Act of October 3, 1917 authorized December 29, 1918.

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The

Journal of Heredity

Vol. XXXVIII **NOVEMBER, 1947** **No. 11**

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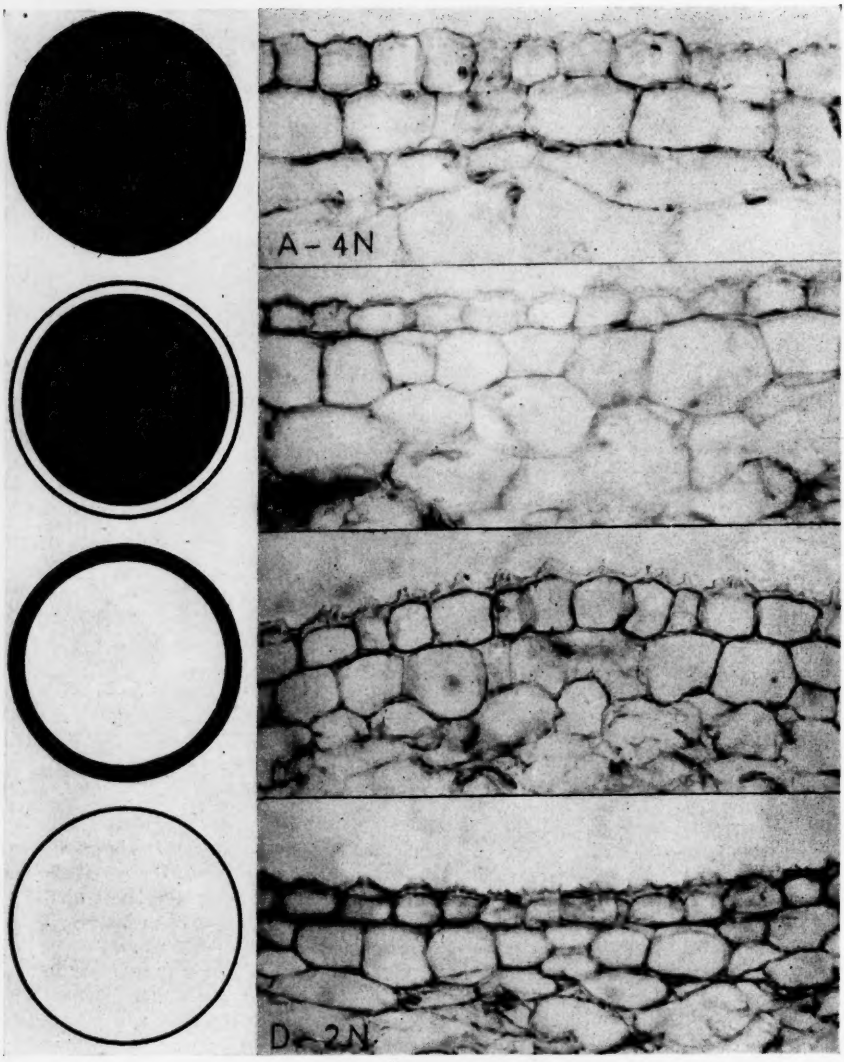


POLYPLOID CHIMERAS IN PINEAPPLE

Figure 1

Photomicrographs of flower petal cross sections showing epidermal and sub-epidermal cells, with corresponding diagrams showing orientation of the chromosomal tissues of the plant. The shaded circles represent tetraploid tissue: the white areas represent diploid tissue. *A*—An all-tetraploid plant; *B*—A plant with diploid epidermis and tetraploid sub-epidermal cells; *C*—A plant with tetraploid epidermis and diploid sub-epidermal cell; *D*—An all-diploid plant.

CHIMERAS IN THE PINEAPPLE

Colchicine-induced Tetraploids and Diploid-tetraploids in the Cayenne Variety*

K. R. KERNS AND J. L. COLLINS

DERMEN, et al,[1] Blakeslee and Avery[2] and others have shown that periclinal chromosomal chimeras frequently appear as the result of colchicine treatment of growing points. Most of these studies used dicotyledonous plants. Similar results have been obtained by treating the pineapple, a monocotyledonous plant, with colchicine. The colchicine treatments of meristem areas of pineapples gave rise, in almost all cases, to sectorial and periclinal chimeras which appear to have included the following distinct types: 1. Tetraploid sectors which involved both epidermal and subepidermal tissues. 2. Sectors having a tetraploid epidermis over a diploid subepidermal core. 3. Sectors having a diploid epidermis over a tetraploid core.

Propagation of slips and suckers which originated in the polyploid sectors of these sectorial chimeras produced three kinds of polyploid clones which are described in this paper.

Material and Methods

The diploid Cayenne pineapple variety which is grown commercially in Hawaii was used in this study to induce tetraploidy.

Two methods of bringing the colchicine into contact with the growing cells were found to give satisfactory results and to be easily applied. A large veterinary hypodermic needle was thrust through the leaf bases of young crowns and slips until the tip of the needle entered the meristem region at which point two to three cc of 0.2 to 0.4 per cent colchicine solution was injected. The large needle caused some local injury to the meristem cells, but this did not appear to affect subsequent growth. The other method was even simpler, for it consisted of pulling out four or five of the younger central leaves of a young crown, then pouring in five to ten cc of the solution. The drug was thus able to reach the dividing cells of the meristem by diffusion through or between the cells from the wounds made by removing the young apical leaves.

Germinating hybrid seeds were also treated with 0.2 to 0.4 per cent colchicine solution for periods ranging from 24 to 36 hours.

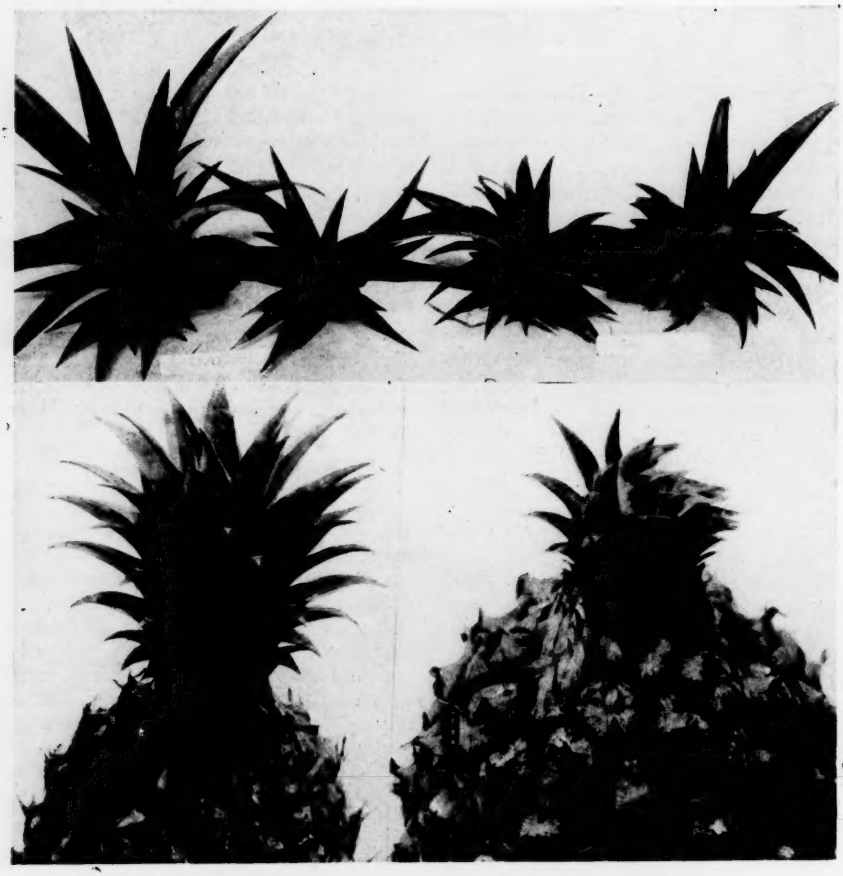
Results and Discussion

The young seedlings resulting from treatment of germinating seeds showed evidence of tetraploidy in the thickening of the leaf bases and a marked thickening and distortion of the growing point. Most of these seedlings failed to continue development beyond an early seedling stage, while some, which were probably chromosomal chimeras, gradually developed into diploid-appearing young plants.

The following discussion, however, is limited to the auto-tetraploids of the Cayenne variety and the two types of diploid-tetraploid chimeras where the effects of doubling chromosome numbers could be studied without introducing new genes as would be the case in the hybrid seedlings.

Colchicine treatment of the growing point of small crowns, slips or suckers seldom resulted in completely tetraploid plants, but instead both sectorial and periclinal chimeras were produced. Diagnosis of the type obtained was deter-

*Published with the approval of the Director as Technical Paper No. 174 of the Pineapple Research Institute of Hawaii.



CHANGES INDUCED BY COLCHICINE TREATMENT

Figure 2

Upper photograph—Normal slip and crown on the left with colchicine treated young crowns at the right, showing thickened and distorted leaf growth. Lower photograph—A normal untreated crown on the left compared with a colchicine treated crown on the right.

THE CRITICAL STAGE OF DEVELOPMENT

Figure 3

Median section through the apical meristem showing the outer single layer of dermatogen cells. The bulge on the surface at the right indicates the origin of a new leaf showing the dermatogen covering the surface of the new leaf without a break in its continuity. If colchicine reaches the incipient bud at this stage, polyploidizing of the outer layer will initiate a chimera.

mined by the size of the stomatal guard cells for the epidermis and of pollen grains for the subepidermal tissue. The difference in size of these cells is shown in Table I. These determinations were verified by chromosome counts in root tip cells. Diploids have 50 and the tetraploids 100 chromosomes.

The young crowns, slips and suckers exhibited a characteristic and unmistakable response to colchicine treatment. The young leaves in the center of the shoot became much thicker than normal diploid leaves, were very hard and brittle and leaf elongation was much retarded. Usually the affected leaves became bent and twisted, indicative of a more rapid growth on one side (Figure 2).

TABLE I.—Differences in cell size in diploid and tetraploid pineapple plants.

Type of plant	Mean diameter in microns		Percentage increase	
	Stomata*	Pollen	Stomata	Pollen
Diploid	24.62 ± 0.16	46.90 ± 0.76	—	—
Tetraploid	31.02 ± 0.13	63.48 ± 0.48	26.0	26.1

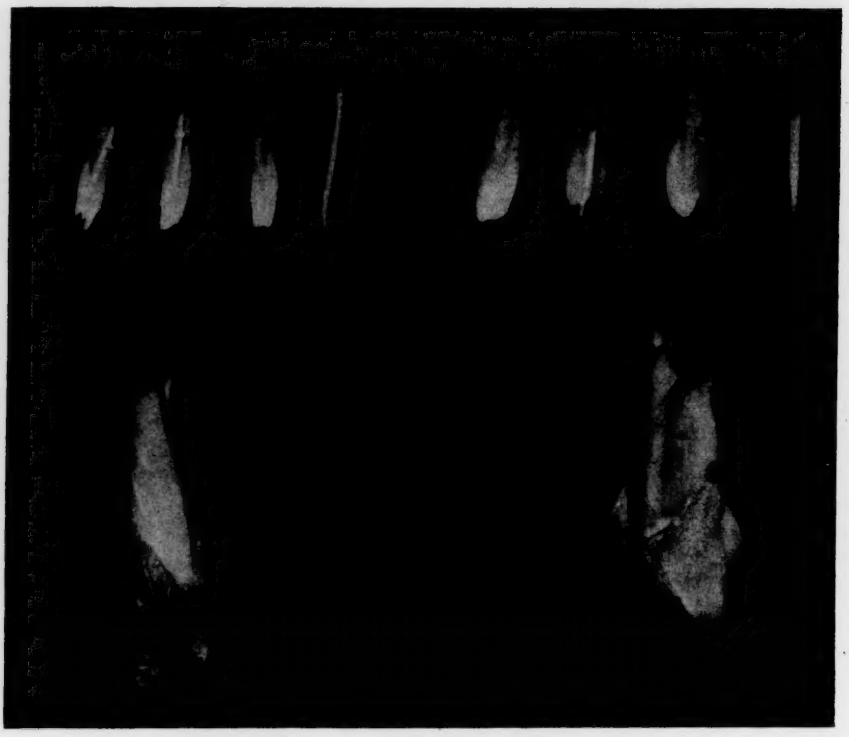
*The stomata of triploids are intermediate in size between the 2N and 4N. Triploids, however, produce almost no viable pollen.

The Origin and Characteristics of Tetraploids and of Two Types of Diploid-Tetraploid Chimeras

A study of the growth and development of the cells and tissues at the apical meristem of the diploid pineapple furnishes an explanation for the manner of origin of these tetraploid plants and diploid-tetraploid chimeras.

Miss Beatrice Krauss* on the evidence obtained from a thorough histological and anatomical study of the pineapple plant, concluded that only two

*Pineapple Research Institute, technical publication in press.



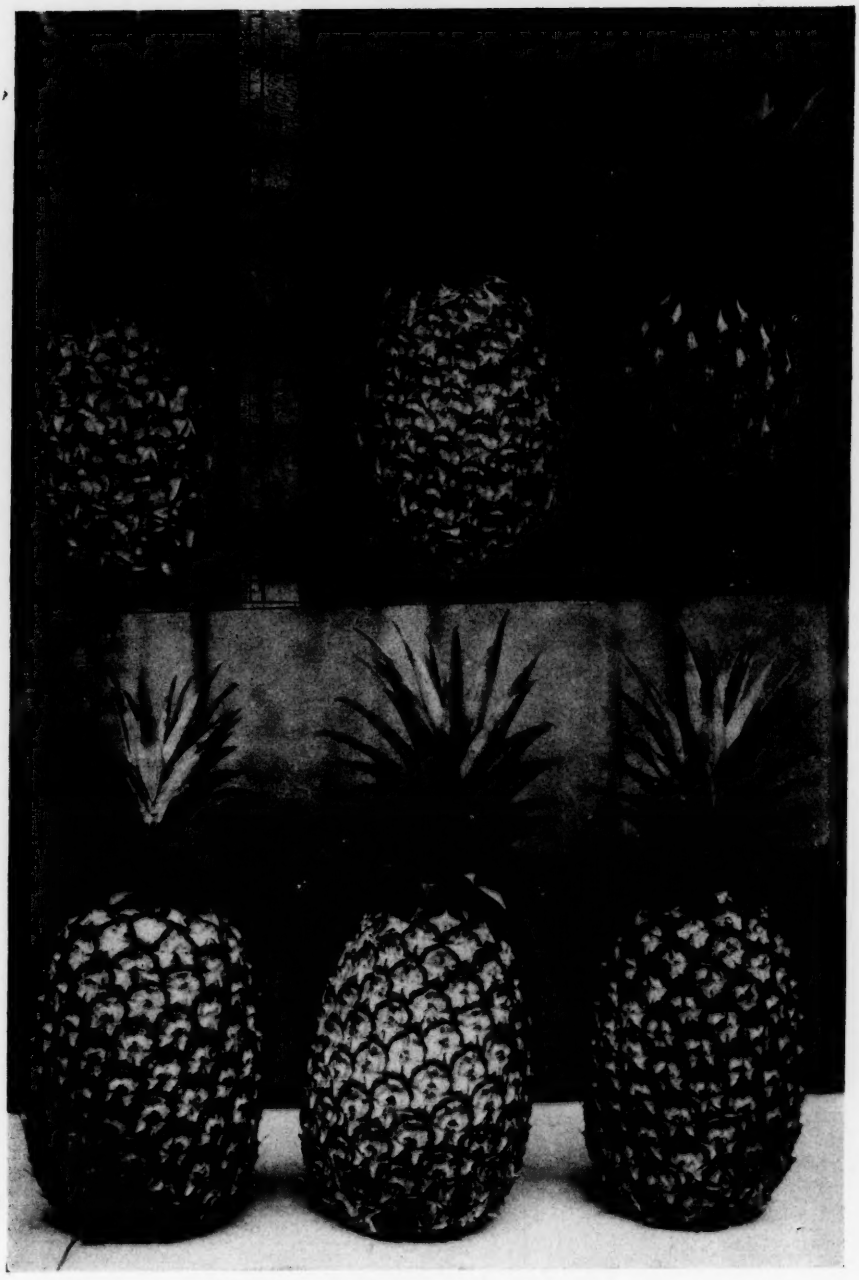
DIPLOID AND TETRAPLOID FLORAL PARTS

Figure 4

Differences in size of floral organs of diploid (left) and tetraploid (right) are illustrated.

distinct germ layers of cells are produced from the undifferentiated apical meristem in the course of the growth and development of the stem of the plant. The dermatogen, a single external layer of cells produces or develops into the epidermis only, while the remaining tissues, all those beneath the epidermis, are developed from the subdermatogen.

The apical meristem in the pineapple consists of a convex dome of rapidly dividing thin walled, undifferentiated cells such as are shown in Figure 3. If colchicine reaches this dome of meristem cells at the time when a few cells of the dermatogen are in a susceptible stage of division but none of the deeper lying cells, only the epidermal layer of the resulting bud becomes tetraploid. Likewise, when only cells of the subdermatogen are in that stage of division, the resulting bud (or sector of a bud) will have a diploid epidermis with tetraploid cells in subepidermal tissues. When cells of both regions are in the proper division stage at the time of colchicine application, both layers become tetraploid, resulting in an all tetraploid bud or a sectorial chimera, having tetraploid cells



TETRAPLOID AND DIPLOID FRUITS

Figure 5

Tetraploid fruits above, on the left two mature fruits and green fruit on the right. Diploid mature fruits are shown below. The tetraploid fruits, like the diploid fruits of this variety, are seedless.

throughout one sector. In addition, sectorial chimeras involving sectors of the two periclinal types mentioned above are frequently produced. Periclinal chimeras of nonsectorial type were established by selecting shoots arising from the periclinal area of the original sectorial chimeras. The periclinal chimeras thus obtained are stable and can be multiplied by asexual propagation.

Comparison of Diploid and Tetraploid Plants

Under similar growing conditions the tetraploid plants reach the flowering stage approximately five weeks later than the diploid, with a corresponding delay in fruit maturity. The fruits of tetraploids are smaller and have fewer but larger eyes (fruitlets), and a lower sugar content. The ascorbic acid (Vitamin C) is the same as in the diploid while the variable characters of acidity and translucence also show no effects of chromosome doubling.

The characters of the periclinal chimeras are determined by the kind of subepidermal cells which make up the greatest portion of the plant. The epidermis is too small a portion of the entire plant to have any readily measurable influence on plant characters. Comparison of the 2N fruit characters with those of 4N and the two chimera types are shown in Table II.

In Table III the plant characters of the 4N are compared with those of the normal 2N form. The measurement of plant height from the ground level to the base of the fruit shows that the 4N stem or central axis is slightly taller than in the 2N. The diploid plant has more functional leaves which indicates a greater internodal length on the tetraploid. The average length of leaves of the tetraploid is the same as the diploid but they have a greater average width, so that the total leaf area does not differ greatly. The tetraploid leaves have a higher percentage of water and consequently a lower percentage of dry matter than do the diploids.

The edges of the leaves of a pineapple plant are curved upward, thus forming a shallow trough which serves to funnel rain from the leaf surface toward the center and base of the plant. In the tetraploid the leaf edges are turned up more than in the diploid so that they have an open U shape in cross section. The lower surface of the leaves is covered with umbrella-like trichomes composed of dead cells which impart a grayish color to this leaf surface. In the tetraploids this grayish color is intensified largely due to the greater size of these trichomes. These also appear sparingly on the upper surface of the leaves and again they are more pronounced on the tetraploid.

The Cayenne variety produces seedless fruits as a result of self incompatability. The doubling of the chromosome number does not appear to have altered this incompatibility for the auto-tetraploid fruits are also seedless. Darlington[4] made the generalization that self compatibility resulted when self incompatible diploids were doubled to produce auto-tetraploids. However, Lewis[7] has shown that the self compatibility or incompatibility of such auto-tetraploids is dependent on the dominance or competitive relationship of the two alleles in the diploid pollen. Our results indicate that the incompatible alleles in the pineapple show neither dominance or competitive relations.

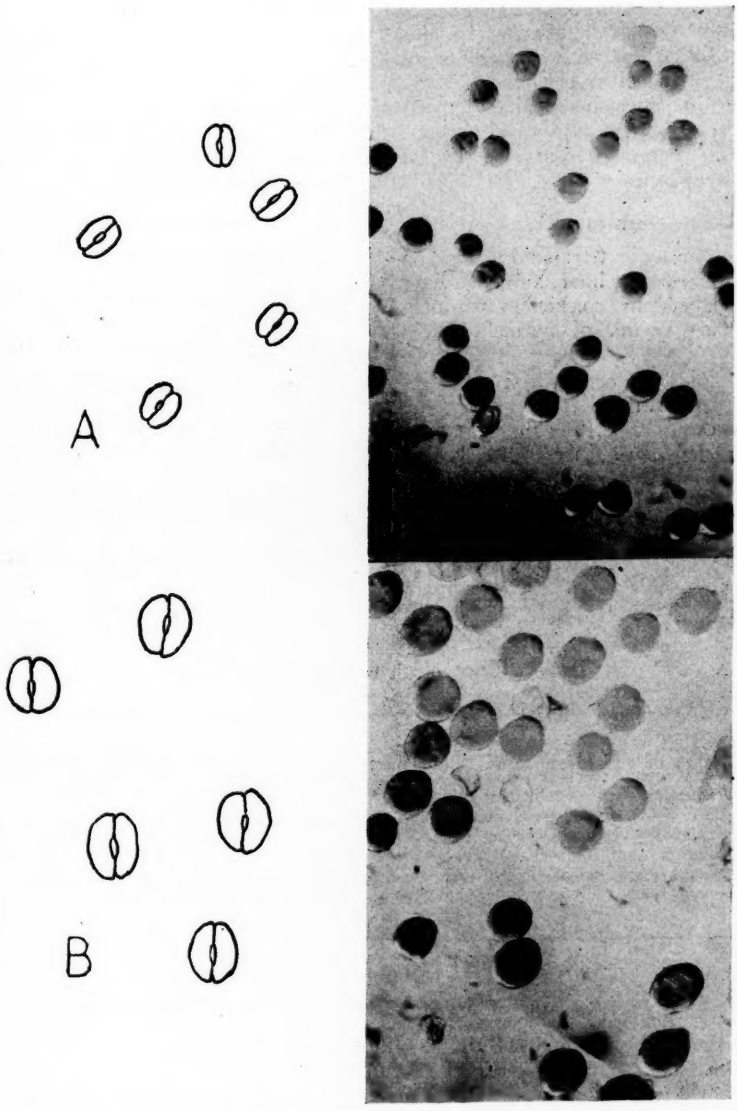
TABLE II.—Comparison of fruit characters of the 2N and 4N pineapples and two types of chromosomal chimeras.

Stomate-pollen	Wt. Lbs.	Eye No.	Eye Wt. (Grams)	Brix	% Total Acidity	Ascorbic Acid*	Translucence
4N — 4N	4.02	104.8	17.1	13.9	0.82	21.0	2.2
2N — 4N	4.00	106.4	16.6	13.8	0.90	20.7	2.4
4N — 2N	5.07	136.0	16.8	15.2	0.67	19.5	2.9
2N — 2N	5.10	144.8	15.9	15.7	0.76	18.9	2.5
Critical odds $3 \times S.E._{MD}$	0.21	26.1	2.1	0.99			

*Mg per 100cc juice.

TABLE III.—Comparison of diploid and tetraploid Cayenne pineapple plants.

Chromosome type	Plant height cm	Number active leaves	Longest leaves: Length cm	Longest leaves: Width cm	Percentage of: Water	Percentage of: Dry matter
Tetraploid	30.5	44.17	65.17	6.15	83.49	16.51
Diploid	28.1	57.00	65.02	5.39	81.79	18.21
$S.E._{MD}$	0.86	2.12	1.01	0.23	0.16	—



STOMATE AND POLLEN SIZE

Figure 6

The stomate and pollen of diploid plants (*A*) are smaller than comparable material in tetraploids (*B*). The pollen and stomate size is determined by the nuclear constitution of the epidermal layers of the plant.

The periclinal chromosomal chimeras obtained in this study, having an epidermis of one type with all the rest of the plant of the other chromosome type (Figure 1), furnish striking experimental confirmation of the conclusions previously derived from histological studies by Krauss.

Summary

In the pineapple, tetraploid plants and two kinds of periclinal chimeras have been produced by colchicine treatment of growing points of normal diploid plants.

Tetraploids in comparison with diploids, have smaller fruits, fewer but larger eyes, lower Brix of the fruit, fewer but wider leaves, increased bloom on the leaves, higher percentage of moisture, less dry matter in the leaves, longer stems and a longer period of vegetative development.

Periclinal chimeras having only a tetraploid epidermis are like diploids.

The auto-tetraploid maintains the self incompatability of the diploid form.

The nature of these periclinal chimeras lends support to the belief that only two germ layers are present in the promeristem of the pineapple.

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◆

Italian Zootechnical Society Formed

The following notice has recently been received from Prof. T. Bonadonna.

The Societa' Italiana per Il Progresso Della Zootecnica (Italian Association for the Progress of Zootechny) was established at Milan on July 17th, 1947. Scientists, technicians and breeders from all over Italy are assembled in this Association aiming to encourage by all possible means zootechnical progress in this country, and to keep a close technical collaboration with all zootechnical and veterinary institutions throughout the world.

Professor Telesdoro Bonadonna of the University of Milan and Director of the Experimental Institute for Artificial Insemination "Lazzaro Spallanzani" has been appointed Chairman of this Association.

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A FAMILIAL LOBSTER-CLAW

Deformity of the Feet and Hands in a Mother and Two Children

EDITH L. POTTER, M.D., AND LUELLA NADELHOFFER, M.D.
The Chicago Lying-in Hospital, the University of Chicago, and the Women's and Children's Hospital

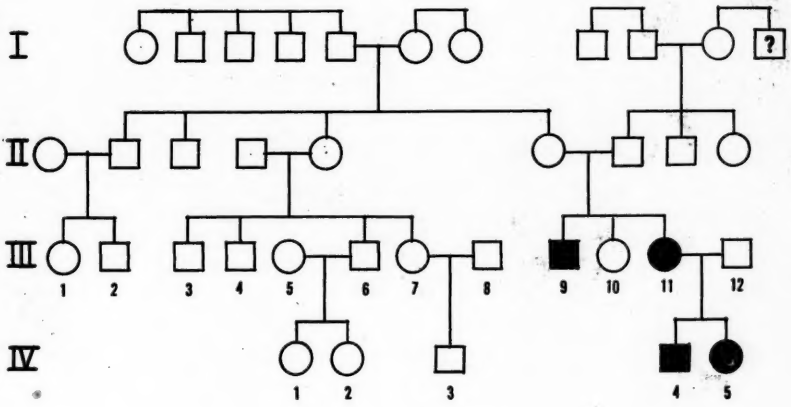


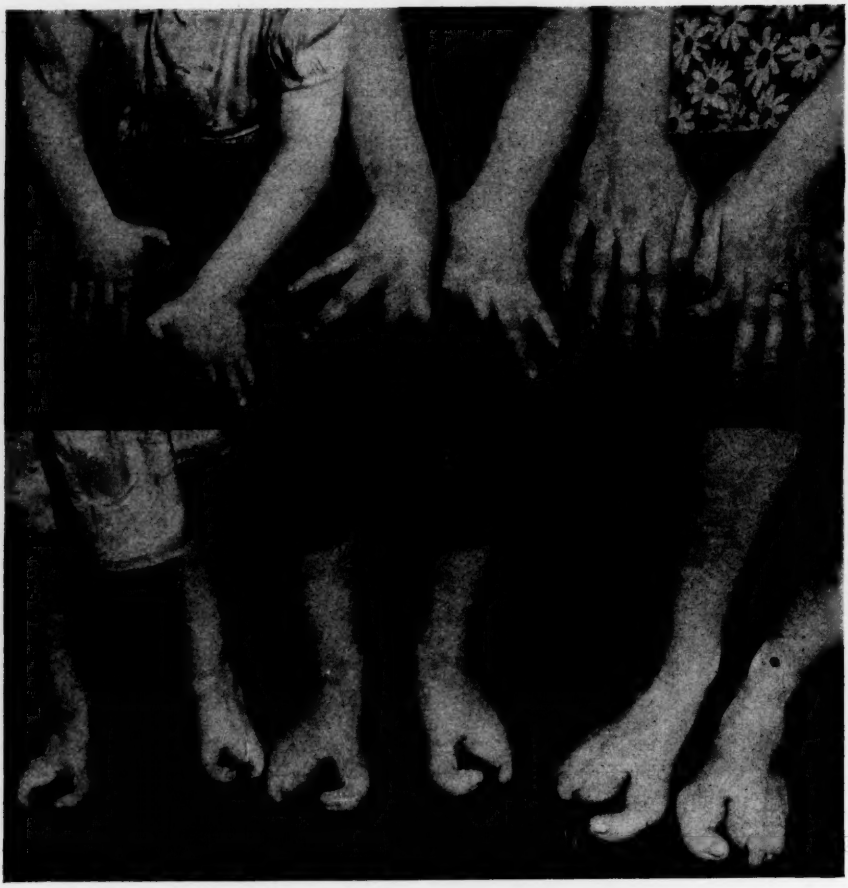
Figure 7

For two generations no history of a lobster-claw condition of hands and feet can be established in this family. Then in the third generation two siblings out of three are severely affected. One of these produces affected childern.

THE hands and feet are among the commonest sites of abnormalities in embryologic development. An increase or reduction in the number of digits or in the number of bones making up the digits are the abnormalities most often observed. Lesions involving the joints or soft tissues are somewhat less frequent.

One of the most severe disturbances encountered in the feet is the so-called lobster-claw or split-foot deformity which consists of an absence or extreme hypoplasia of the central metatarsal bones, absence of the phalanges normally found distal to those metatarsals and a soft tissue disturbance leading to fusion of the medial and lateral digits into two masses. The second metatarsal is almost always absent or very hypoplastic. The third and fourth metatarsal bones vary and may be normal, reduced in size or absent. Phalanges are usually not present unless the metatarsal bone to which they are normally attached is of approximately normal form. The phalanges are fused by soft tissues into two masses broad at the base and tapered at the end. The terminal phalanges are set at such an angle that they bend toward each other and give the appearance from which the deformity takes its name. The condition is almost always bilateral.

Similar deformities of the hands have



TWO GENERATIONS OF DEFORMED DIGITS

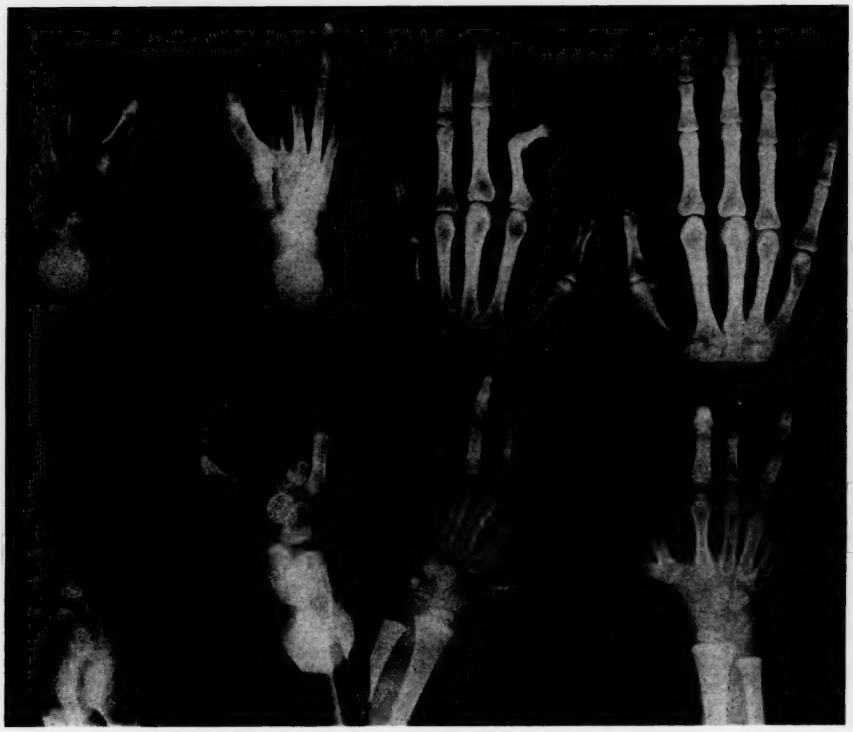
Figure 8

The hands of the mother (III-11) are not as seriously deformed as are those of her children. Such variation in extent of deformity has been noted in other pedigrees.

been observed but seem to be much more rare than those involving the feet. Some type of hand malformation, however, is almost always associated with the lobster claw deformity of the feet.

The G Family

The individuals to be described in this paper are a mother and two children all of whom have severe malformations of the hands and feet (Figure 8). The mother (M.G.) is one of three siblings; the eldest was a brother who died at the age of 19 of pneumonia and is stated to have had feet similar to those of his youngest sister; the second was a girl with no known malformations who died at 13 of an unrecorded cause; the third



AFFECTED EXTREMITIES OF DAUGHTER AND MOTHER
Figure 9

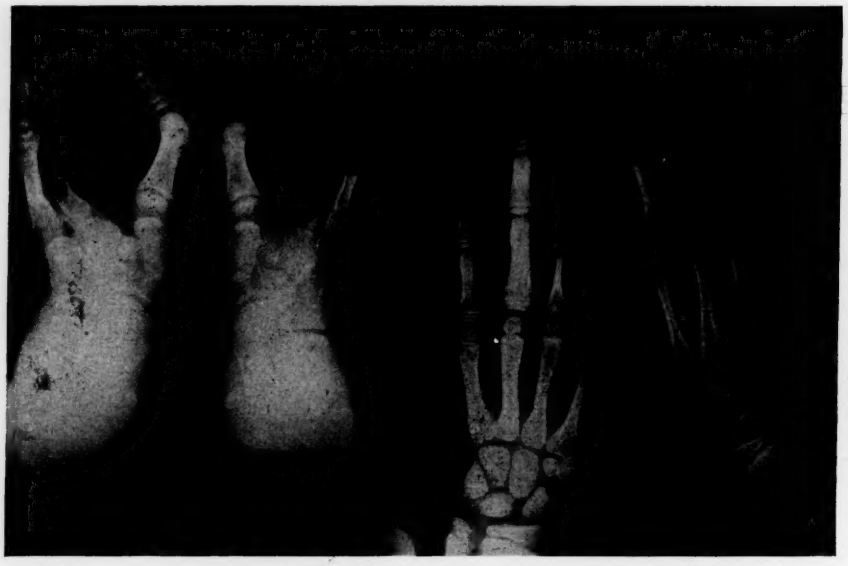
The mother's extremities are less severely affected than are her children. This varied expressivity, due either to modifying genetic factors or to varied environmental stimuli, is not unusual in dominantly inherited skeletal defects.

child is the eldest of the three individuals described in this report.

It has been impossible to examine any other members of the family, but M.G.'s parents, their brothers and sisters and all of their offspring except M.G. and her sibling are stated to be normal. Maternal and paternal grandparents and their brothers and sisters were also free of known malformations (Figure 7).

The deformity of the hands and feet of the mother (M.G.) are shown in the accompanying photograph (Figure 8) and x-rays (Figure 9*A*). The hand deformity is slight and consists principally of an abnormality of the terminal portion of the proximal phalanx of the first finger of the left hand. As a result of this abnormality the two distal phalanges diverge medially at almost a 90 degree angle from the straight line.

The feet are more severely deformed than the hands. The tarsal bones are normal but the second metatarsal bone on each foot consists only of a short rudimentary fragment of osseous tissue. The third metatarsal on each foot is normal, but the phalanges which should arise from the second and third metatarsals are missing. The fourth and fifth toes are webbed. An abnormal cleft is present between the first and third metatarsals and is in the position which should normally be occupied by the sec-



MISSING THUMBS—GIANT HALLUCES
Figure 10

In the hands of IV-4 the bones not missing are essentially normal, whereas in the feet there is a more fundamental derangement of structure and proportion.

ond metatarsal bone. The lateral curvature of the phalanges of both first toes produces the characteristic claw-like appearance.

This woman is married to a man who is in good health, who has normal hands and feet and who has no known malformations. She has had two pregnancies. Both children have malformations of the feet which are more severe but otherwise similar to those of their mother, and both have marked deformities of the hands.

The feet of the children, as can be seen in the accompanying x-rays, disclose metatarsal and phalangeal bones which show a greater divergence from the normal than do those of the mother. The feet of the daughter, D.G., age 3, are both composed of presumably normal tarsal bones and approximately normal first and fifth metatarsal and phalangeal bones (Figure 9*B*). The second and third metatarsal bones are lacking in each foot and the fourth metatarsal is short and rudimentary. The left foot of the son, S.G., age 6, is similar to that of his sister but the right shows a fourth metatarsal of normal length and a rudiment of a third metatarsal (Figure 10). Phalanges are present only in relation to the first and fifth metatarsal bones.

The hands of the two children are surprisingly different from those of the mother. While hers are only slightly abnormal, those of both children are very deformed. Those of the son show a reduction in the number of phalanges of the first and second fingers on each hand and a complete absence of the thumb of the right hand. A short, rudimentary bone is the only suggestion of thumb that is present on the left hand.

The hands of the daughter exhibit the only evidence of duplication of bones that is present in any of these individuals (Figure 9*B*). Although she, too, lacks part of the phalanges of the first and second fingers, she has a partial duplication of the first metacarpal bone

on each hand and an excessive number of phalanges. A portion of one of the phalanges of the left hand had been removed before the x-ray was taken.

Discussion

The lobster-claw deformity of the feet has been reported in several members of a single family by a number of observers. It is almost always associated with malformations of the hands. According to Gates* one family in which 44 members were affected in five generations has been observed. The disturbance is generally thought to be inherited as a Mendelian dominant and never to appear in a child unless present in a parent. It must appear originally as a mutant.

Of interest in the present family is the fact that the first known appearance of the anomaly was in two siblings whose parents and grandparents had no recognizable defects. Three possibilities present themselves:

(1) Assuming that a single gene is involved in this defect, its expressivity varies greatly, as is evidenced by the slight defect of the mother's hands as compared with that exhibited by her children. This might be due to the action of modifying factors, which in the preceding generations might even have masked the defect so effectively that it was not recognized. Had the defect of the mother's hand been expressed in one of her feet, it might easily have been overlooked, or considered the result of ill-fitting shoes, rather than an inherent abnormality. Segregation for such modifying genes could then result in a more extreme expression of the defect in generation IV.

(2) It is highly improbable that the two siblings in generation III are due to two independent mutations. Hence the possibility is suggested that a dominant mutation to the lobster-claw gene occurred in the germ-tract of either the father or the mother of III-9 and III-11. Had this occurred early in development, a large sector of the ovary or testis would be heterozygous for the lobster-claw mutation, which would not be exhibited by the individual carrying this newly-arisen defect.

(3) There is also a possibility that the defect is recessive, and that the normal mate of III-11 also carried the defect. In view of the extreme rarity of this defect this is unilkely unless III-11 and III-12 are related, which as far as our information goes, is not the case.

In the light of all the available evidence, alternative (2),—that a dominant germinal mutation has occurred—appears to be the most likely hypothesis to account for the mutation.

Summary

A mother and two children suffering from severe malformations of the feet and hands are described. The malformations are similar except for a greater degree of abnormality in the children. A sibling of the mother also had malformed feet. The foot defect is characteristic of the so-called lobster-claw or split-foot deformity. The malformations of the hands consist principally of a partial absence of phalanges.

*Gates, R. R. *Human Genetics,* The Macmillan Company, New York. 1946.

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National Research Council Announces Fellowships

THE National Research Council has just announced a number of opportunities for advanced study and research in the natural sciences for the academic year 1948-49. Postdoctoral fellowships carrying a stipend of $2,500 plus travel allowances are offered in the biological and agricultural sciences, anthropology, psychology, geology, geography, and the physical and mathematical sciences. Candidates must have completed the requirements for the doctor's degree.

Another fellowship program in the chemical and biological sciences, sponsored by Merck and Company, is designed to stimulate an interest in fields of study requiring knowledge of more than one science. Stipends range from $2,500 to $5,000 plus travel allowance. Educational prerequisites are similar to the requirements for the postdoctoral fellowships.

For further information apply to the National Research Council Fellowship Office, 2101 Constitution Avenue, N. W., Washington 25, D. C.

GENETICS AND THE EVOLUTION OF CIVILIZATION

THIS splendid book*, an outgrowth of the Messenger lectures delivered at Cornell in 1945, consists of six chapters, two by each author. The book's tone is quite even; it is obviously written for the lay student of genetics but has particular value for the thoughtful physician. With each page so full of important factual data and the consequent philosophical conclusions, *Genetics, Medicine, and Man* does not qualify for bedtime reading. The reviewer, a man mid-wife, had the misfortune of attending college and medical school before genetics was part of either curriculum and he found it necessary to read with pencil in hand.

Dr. Muller begins with a discussion of genetic fundamentals. One of many points the physician reader may well remember is that genes may be so timed in their action that they do not assert their effect until the organism is fully adult, "Development is really not finished until death ensues, though it gradually slows down its pace."

Dr. Muller emphatically states that any finished characteristic of the adult body does not depend upon one gene and one gene alone "but depends upon the working of many genes in cooperation, and a change in any one of these may change the quantity or quality of the result." However certain genes are more important than others in affecting the character; some are truly essential to its very occurrence, while others simply modify it. He writes, "there can be no greater blunders in genetics than those so rife in the early years of the science of confusing the gene itself with the character caused by it, and of assuming a fixed one-to-one relationship between them." The most objectionable of the various fallacies to which this crude and naive point of view lead was the belief that if a certain trait is hereditary it cannot also be influenced by the environment, and conversely, if influenced by the environment it cannot at the same time be hereditary.

Mutations

In discussing mutations, Dr. Muller concludes "since the mutations occur fortuitously, the great majority . . . are detrimental in their effects, as we should expect of blindly induced changes in any complicated organization."

Dr. Muller succinctly expresses a geneticist's summary of evolution. "If we are willing now to follow backward in time . . . we arrive at a stage in which there was only one gene of the simplest possible type. . . . Having, however, the property of mutation and of being able to duplicate even its mutant form, its descendant genes necessarily diversified in the course of time; and those that happened to have chemical effects that in any way aided them in surviving or in making use of the materials around them for their own duplication naturally multiplied the most."

In the second chapter Dr. Muller praises sex, not from the ordinary moral viewpoint, but from the geneticists' chaste focus, stressing the advantage that sex bestows in making speedier evolution possible. He writes "sexual reproduction, through its essential features of independent segregation and crossing over—in one word, recombination—acts as the handmaiden of evolution. . . . It has no primary use for living things apart from this."

Dr. Muller has a gift for popular simplification as the following quotation in which he discusses "speciation" attests: "One section of a population has in some way become separated from another section so long as to have accumulated many mutations which, though suitable for it, form a system of genes that is in one or more respects incompatible with the system in the other section.

*MULLER, H. J., C. C. LITTLE, and L. H. SNYDER. *Genetics, Medicine, and Man.* Cornell University Press, Ithaca, New York, 1947. 158 pages including index. $2.25.

Then an attempt at intermixture . . . find[s] them unable to mate effectively Two such groups, now having attained the rank of a separate species, are destined forever more to go their separate ways, in increasing divergence from one another."

He points out that it is advantageous "for there to be semi-isolated groups within each species as a whole, carrying on numerous genetic experiments for it in their more or less separate laboratories." If the professional anti-negro or anti-semite had enough intelligence to read and understand this last sentence he might find reason to question the biologic soundness of the creed that only his kind of white man should people the world. Dr. Muller concludes by pointing out that when a species gives up its many isolated intraspecies groups in order to form one huge homogeneous interbreeding population, it takes the great genetic risk of putting all its eggs in one basket.*

Dr. Little begins his contribution with the consideration of parental influence, by which he means all recognized or potential types of biologic influence exerted by parents on offspring including even mother's milk. He discusses recent advances in the field under three major groupings: morphogenetic, emotional-endocrine, and psychosocial.

Under the first category he reviews some of the more recent work on lethals, genetic differences determining fertility, and the inheritance of the rate and extent of growth. From consideration of normal growth with its orderly and controlled manifestations of cell division, Dr. Little passes on to the nature of the parental influences which affect the origin and support of centers of uncontrolled and disorderly growth resulting in tumors. He points out that the male and female have equal weight in the hereditary aspects of mouse lung tumor; on the other hand the maternal parent is the more important in determining whether mouse young will develop epithelial mammary gland tumors. In vulnerable stock mother's milk was also shown to have an effective role in stimulating the occurrence of this tumor in offspring.

He summarizes the effect of hybrids by stating "Conflict between different genetic trends or degrees of function may well prove to be one of the major causes of unbalance in the internal environment, thus leading to disease." He suggests that schizophrenia may have some such etiologic background.

Sex-ratio he suggests may also have a genetic factor, racial inbreeding being associated with a low sex-ratio. He does not state whether a genetic factor decreasing fetal salvage through increased abortion is associated; however the reviewer would expect this to be the case.

Endocrines

When discussing emotional-endocrine genetic factors, Dr. Little refers to Stockard's investigations upon the genetics of body form in dogs as related to the endocrine type. Achondroplasia which produces the characteristic short twisted legs of the dachshund is a clear mendelian dominant quite distinct genetically from the skull achondroplasia of the English bulldog. Various neuromuscular genetic abnormalities of mice: the waltzing, jerker, shaker, and variant varieties are discussed. It appears that each is caused by a separate gene. Genetic dwarfism in mice is a distinct entity in which growth is concluded at the seventeenth day of post-natal life. Both the anterior pituitary and thyroid glands are greatly reduced in size. The gene is a mendelian recessive. Daily implants of fresh rat pituitary induce renewed growth terminating in full adult size, except for the anterior pituitary which remains permanently dwarfed.

The analysis of the genetic basis of human emotional behavior is a field for the future. Such study, Dr. Little suggests, has been greatly retarded, by "the blind and impractical worship of euphonious but sterile dicta of unscientific leaders who have mistaken declarations of human equality for truth."

*See excerpt on page 340.—Ed.

The third environmental level is the psychosocial. Dr. Little decries the common use of anthropoid apes in this sphere of investigation; the disadvantages being their delayed puberty, the small litters, and expense. Unquestioned genetic factors in both the speed and degree of learning have been demonstrated in strains of mice by use of the maze. In the relatively unexplored field of the genetics of social factors, the domestic dog with its constant, deliberate selective breeding for the establishment of various types of behavior offers an untapped source of material.

Cancer

Dr. Little calls his second chapter "Growth and Individuality." In this essay he reviews his own field, the genetics of cancer.

He writes "certain types of cancer represent failure on the part of growth regulatory agencies in the body to establish a proper balance. Others follow a failure to maintain such a balance under the disorganizing influences of differential rates of aging among different systems of tissues and organs. As mammals age chronologically, various endocrine and other internal influences which maintain balanced growth begin to age physiologically and to create thereby unbalance within the body. This unbalance may result in local failure to exert controlling influences which hitherto have held growth in check. The result will be areas of insurgent growth especially where excessive physiological strain due to chronic irritation has been present."

Attention is then turned to embryonic tissue growth. The author uses as an example the continuous series of tissue cultures of chick embryo fibroblasts which have been maintained without decrease in growth rate, or tendency to differentiation, for many times the life span of a fowl. Removed from the inhibiting and regulative influences operative in the body they continue uninterrupted their embryonic type of behavior. Cell regeneration has some components in common with this; the process of active cell division and the regeneration of new tissue continuing only until the previous balance of structure and form is reached; the reestablished balance acting as the regulatory inhibitor of increased cell division.

I must challenge one statement that Dr. Little makes in the further elaboration of regeneration. In discussing human identical twinning he writes, "It has been clearly shown that the tendency to form such" (monozygotic) "twins can be greatly influenced by the type of sperm." Most of the current twin literature will not support this statement; the sperm borne tendency is proved for the dizygotic variety, but at best it is but faintly suspected for the monozygotic type.

On the basis of tumor susceptibility and tumor resistances in inbred female mice as well as the uniformity of litter size, investigations have shown that the individual reaction for the strain is best demonstrated in the fully adult animal; very young and very old females are more variable in their reactions.

Very early infancy and senescence are biologic periods of disintegration which contrast with the balanced control and organization characterizing adulthood.

The contributor of the final third of the book, Dr. Snyder, calls his first chapter "Human Heredity."

The author reminds us that from a genetic viewpoint man is not a satisfactory animal because of his highly heterozygous nature. In man genetic material is either collected by obtaining family pedigrees where at least one member has a rare physical or physiological characteristic, or by determining "test characters" such as blood agglutinogens or phenyl-thiocarbamide non-tasting in a sample population.

Twins have made possible a third field of human investigation, the effect of non-genetic influences on genetically similar individuals (monozygotic twins), and genetically different individuals (dizygotic twins). Dr. Snyder pokes fun at the nonsensical dinner table cliché, "Is such and such a thing due to heredity or environment?" Dr. Snyder rephrases

the question in biologically acceptable verbiage: "How much of the variability or similarity in this trait is due to differences in the genetic make-up of the individuals concerned, and how much is due to the exigencies of the environment in which they have developed?"

Variation may be the result of differences in either the genetic or non-genetic factors; more commonly it is the result of differences in both. It has been shown that susceptibility to both diphtheria and paralytic poliomyelitis is dependent upon a recessive gene substitution, and immunity upon its dominant allele. Of course, exposure to disease is variable, so we are dealing with two variables, the genetic makeup of a population and the exposure rate.

Medical Genetics

The last quarter of the book is probably the most interesting for the medical reader and the most difficult for the reviewer to appraise and summarize. In it Dr. Snyder discusses the many praccal applications of the preceding theoretical material.

These applications are: first, genetic prognosis, advice concerning marriage and childbearing; second, aid in the diagnosis of obscure conditions on the basis of genetic data; third, the institution of preventive measures against certain diseases and abnormalities on the basis of a specific genetic background; fourth, the medico-legal application of test characters in non-paternity, etc., and fifth, the proposal of an intelligent eugenic program on scientific genetic groups. Dr. Snyder discusses each of the five subheadings giving examples. The readers of this review can readily supply examples for one, two, four and five. Under three, prevention, he bespeaks the institution of prophylactic measures on the basis of the genetic history. It is sometimes possible to prevent an hereditary abnormality or disease in the relatives of a patient that might otherwise appear. He gives as example, xanthoma tuberosum, which is a storage disease, one of the lipoidoses. A relative of one so afflicted should have his blood cholesterol and cholesteral esters checked. If a pathological level is found the normal appearing relative is protected by a dietary regimen. The prophylactic removal of the spleen in members of a family tainted with hemolytic icterus, who themselves show occult evidence of the condition, is advanced as a second example of genetics applied to preventive medicine.

In the final chapter Dr. Snyder discusses "The Mutant Gene in Man." He begins by considering the spatial relations of autosomes and allosomes. The latter's spatial relations are far more complex than this misguided obstetrician thought, for he considered the *Y*- and *X*-chromosomes as having nothing in common, being almost antithetic. Dr. Snyder corrects this concept by showing that there are homologous portions of the *X*- and *Y*-chromosomes as well as non-homologous portions of each. This concept is fundamental in explaining sex-linked (red-green color blindness, hemophilia, etc.), and incompletely sex-linked characters (total color blindness, spastic paraplegia, etc.).

Under the physiological aspects of the human mutant gene, penetrance is first discussed; penetrance being a statistical concept of the regularity with which a gene produces its effect. If a recessive gene results in a certain trait in every homozygous individual, or if a dominant gene results in a certain effect in 100 per cent of the individuals carrying it we are dealing with complete penetrance. The genes for blood agglutinogens are good examples of complete penetrance. On the other hand many genes have partial penetrance: e.g., diabetes mellitus with 10 per cent penetrance, and leukemia with a fraction of a per cent. A dominant gene with low penetrance will cause a sporadic appearance of the trait in the pedigree, so that it can only be differentiated from a recessive gene by comparing the proportion of affected parents, siblings, and offspring. The degree of penetrance may be the same or different for the two sexes, an example of the later being the

recessive gene for pyloric stenosis which has almost complete penetrance for males but much reduced penetrance for females. Another modifying attribute for human genes is "expressivity," whether its effect is the same from person to person. The dominant gene for allergy results in variable expressions: asthma, angioneurotic oedema, eczema, hay fever or urticaria. Recent researchers have demonstrated that epilepsy is dependent upon a dominant autosomal gene with variable expressivity. The basic expression of the gene is cerebral dysrhythmia, abnormal brain waves. But only about one person in twenty who has cerebral dysrhythmia will manifest classical epilepsy, a spilling over of this trait into the peripheral nerves.

In discussing the broader phylogenetic aspects of medical genetics Dr. Snyder writes: "A common misconception regarding genetic traits is that a character dependent upon a dominant gene will in time increase its proportion in a population merely because the gene is dominant. Actually, it will not. As long as all individuals in a large population have equal opportunities to produce viable offspring, a dominant gene will not increase in frequency with respect to its recessive allele in the absence of mutation and selection. Rather the two (or more) alleles will maintain constant frequencies from generation to generation."

The Messenger Lectures, according to the terms of the founder's bequest, are to be "lectures on the evolution of civilization." The contribution of genetics to this high end is not always generally recognized. One non-geneticist who has read here with pleasure and profit, can only hope that this book will serve to spread more widely this deserved recognition.

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Sex and the Gamble of Selection

An Excerpt

WHEN a species gives up one of these procedures—either the splitting into simultaneous separate species or into many semi-isolated intraspecies groups—and particularly when it gives up both, so as to form just one huge interbreeding population, it takes the desperate chance of putting all its eggs in one basket. That basket is, to be sure, guarded in a very conservative manner. For, although such a species keeps the advantage of sexual reproduction within its own ranks, no mutations get a chance to be tried that fail to show an immediate profit, and progress thus becomes largely confined to the safe, sane, and obvious. This species is, however, likely in the end, as a result of its excessive genetic caution, to find itself outmoded in comparison with the results of some of those gambling chances which, taken tentatively, may at some points be called for. The only way to remedy such a situation, while retaining the unitary group, is of course to replace the effects of nature's experiments with those of intelligent, very farseeing design, in genetic as well as in other spheres.

All this becomes the more true if, within a species, there comes about for any reason a relaxation of selection. For even within the species as a whole the primary advantage of sexual reproduction, recombination, can be gained only if the better adapted recombinants really have a chance to multiply more than the others. Without this, the constant pirouetting of the genes is a play that has lost all its biological function. In such a situation there will even be a gradual creeping up of the frequency of detrimental mutant genes, if they are allowed to accumulate without being somehow pruned off as fast as they arise. Thus in a species which is no longer undergoing adaptive genetic changes by making the sacrifices that selection requires, sex is a vestigial phenomenon, a feature that is rendered helpless and that has outlived its own usefulness. But, for those species that pay a little of their present income into a fund for the future, the perpetual trial of shifting combinations is the biological counterpart of what in human economy is the function of scientific research. For, given selection along with recombination, there results a sort of genetic profiting by experience, a process which in the course of ages has made the forms of life on earth those marvels of seeming design which we find them to be today.—(H. J. M., *Genetics, Medicine and Man*, page 62-63.)

LINKAGE STUDIES OF THE RAT

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VII. Shaggy, a New Dominant

THREE curly hair mutations of the rat have previously been described and their linkage relations investigated. Two are dominant, curly and curly$_2$, which are shown in heterozygous examples in Figure 11*A*. The third, which is recessive, is known as kinky. A homozygous example is shown in Figure 11*B*. The genes of all three lie in different chromosome pairs, as is shown by their free recombination in crosses with each other. Curly lies in chromosome II with the genes for anemia, incisorless and brown. Kinky lies in chromosome IV being linked with stub. No linkage has been discovered thus far for curly$_2$.

Of the three mutant genes, curly$_2$ has the greatest effect in causing curvature of the hair including the vibrissae, as is shown (not too clearly) in Figure 11.

Shaggy is a gene which in its effects on curvature of the hair is intermediate between curly and curly$_2$. It made its appearance in 1945 in a strain of inbred albinos at the Wistar Institute. As in other curly hair mutations its presence can be detected easily in new born young by the curvature of the vibrissae, when the body elsewhere is devoid of hair. This makes its study easier.

We shall see that shaggy lies in the same chromosome as curly, which it resembles and with which it is closely linked.

When curly and shaggy are crossed with each other, the curving effect is greatly increased in F_1 animals so that it equals or exceeds that of heterozygous curly. Compare Figure 11*A* left, with Figure 11*B*.

To discover, if possible, whether shaggy is linked with any other known mutant genes of the rat, crosses have been made with other stocks as indicated in Table I. Shaggy was associated originally with the albino gene. A shaggy albino was crossed with a colored rat, and the F_1 shaggy colored individuals were then backcrossed to normal albinos, the double recessive. Shaggy colored and normal albino young would represent crossover classes. These were found to be even more numerous than the non-crossovers, 58:49, but the difference is not statistically significant. No indication of linkage between shaggy and albinism is found.

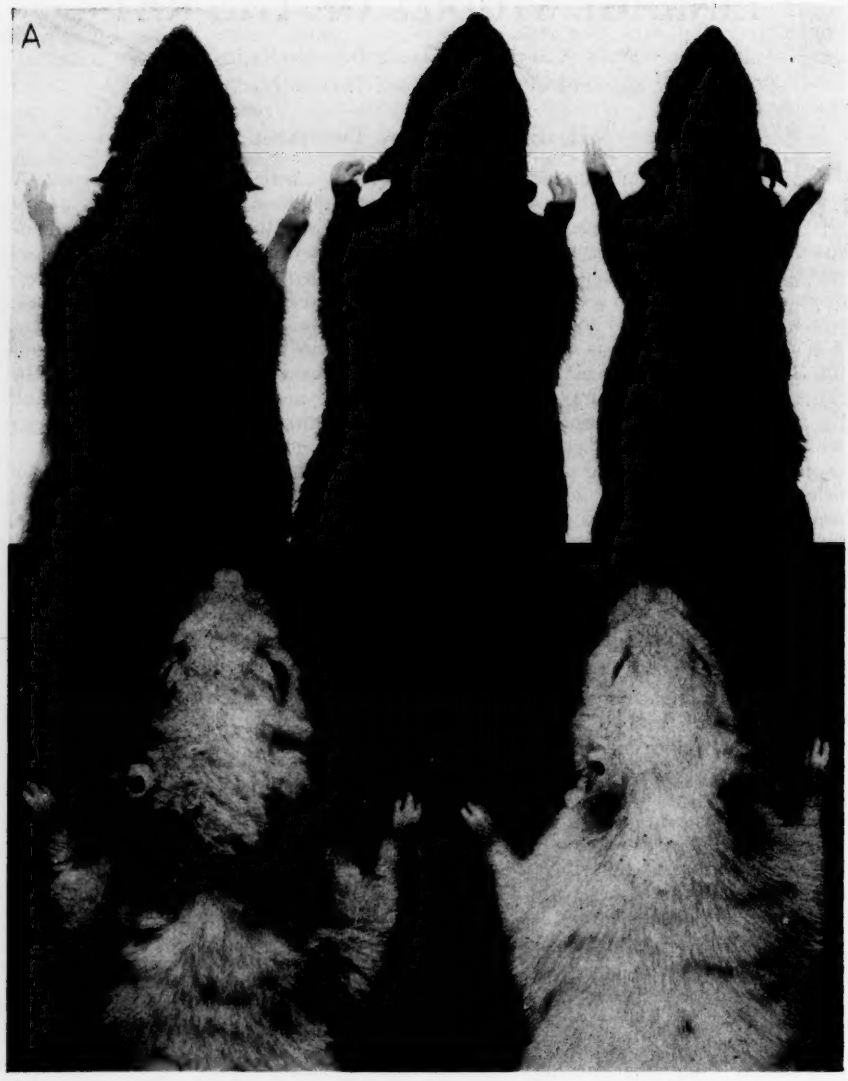
By a similar process it was shown that shaggy is in all probability not linked with cataract, jaundice or blue, since in backcrosses from repulsion crosses equality of crossover and non-crossover classes is found, within limits of the probable error. See Table I.

But when shaggy was crossed with curly, and the F_1 shaggy-curly heterozygotes were crossed with double recessives, (i.e. rats neither shaggy nor curly), a surprising result was observed. All the young in the first few litters recorded, had curly vibrissae at birth, showing that each indivdiual had inherited either the curly or the shaggy gene. This suggested that the two are alleles. But as additional litters were produced it was found that an occasional individual had no curved vibrissae. Such an individual having inherited *neither* curly nor shaggy would be a crossover.

The F_1 male seen in Figure 11*B*, left, sired 25 litters of young by normal females, four of which litters contained each a single normal (crossover) rat, with littermates having curved vibrissae

TABLE I.—Tests for linkage (repulsion) between shaggy and certain other genes.

Gene	Total	Cross-Over	Non-Cross	Dev./P. E.
Albino, *c*	107	58	49	4.5/3.5
Cataract, *Ca*	92	47	45	1.0/3.2
Jaundice, *j*	94	45	49	2.0/3.3
Blue, *d*	75	39	36	1.5/2.9
Curly, *Cu*	461	18	443	212.5/7.2
Brown, *b*	125	64	61	1.5/3.8



CURLY, SHAGGY, AND KINKY

Figure 11

A—Three dominant curly hair mutant rats shown in heterozygous examples. Left to right, Curly$_n$, Curly and Shaggy. *B*—An F_1 Shaggy $\times$ Curly rat, left; a homozygous kinky rat, right. The shaggy-curly combination is found in most of the backcross individuals, and the rare individuals with straight vibrissae represent crossovers.

to the number of 5, 7, 8 and 12 respectively. His total progeny in these 25 litters numbered 251, of which four normal young represent 1.55 per cent. Theoretically there should have been a like number of crossovers of *both* curly and shaggy in the coupling relationship. These would not be easily distinguished in the newborn state, at which the enumeration was made, but assuming that they occurred we may estimate the total crossovers as 8 in 251 young or 3.2 per cent.

F_1 sisters of the rat shown in Figure 11*B*, left, were mated to normal albino males producing 23 litters in five of which occurred a single normal (crossover) individual. The total number of young recorded was 210. If 10 were crossovers, the percentage is 4.8. In this we have a new illustration of the principle that in mammals crossing over occurs a little more frequently in females than in males.

Combining the results of both series of backcrosses, we reach the conclusion that the crossover percentage between curly and shaggy, disregarding sex, is close to 4.0.

The question now arises, does shaggy lie between curly and brown, which are known to be about 45 crossover units apart, or is shaggy more distant from brown than curly? To answer this a repulsion cross was made between shaggy and brown, and the F_1 was backcrossed to the double recessive, brown normal. Four clases of young were produced as follows: brown normal, 42; brown shaggy, 30; black normal, 34; black shaggy, 19. The middle two classes are crossovers totalling 64, the non-crossover classes total 61, a non-significant difference. So far as this evidence goes, it indicates that shaggy is more remote from brown than curly is, but the evidence is inconclusive. Assuming that this indication will prove capable of verification, the linkage map of chromosome II will become, on present evidence:

Sh	*Cu*	*an*	*in*	*b*
0	4	14.3	28	49

Note that the map distance between shaggy and brown is close to 50 per cent, so that a direct test for linkage between the two could be made conclusive only by very large numbers of backcross young.

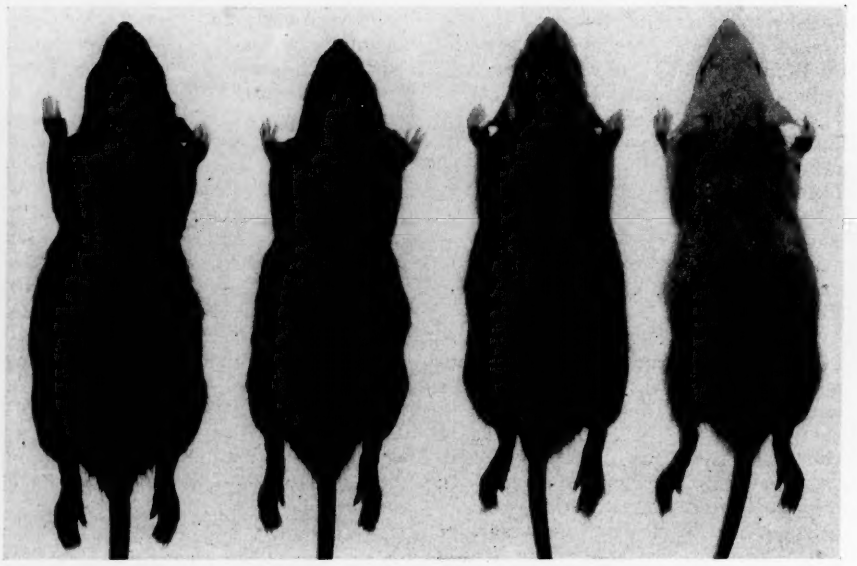
VIII. Fawn, a New Color Dilution Gene

IN 1945 a new recessive color variety made its appearance in a strain of inbred blue rats at the Wistar Institute. Mutant individuals were a pale lavender in color, much lighter than ordinary blue animals of the parent strain. The new type was called fawn by Dr. King.

A foundation stock of fawn rats was sent to Castle for collaboration in the study of the new mutation and its linkage relations.

The fawn variety was found to be true breeding. Fawn mated to fawn produced in three litters, 17 young, all fawn like the parents. Fawn, mated to blue animals of a strain in which no fawn individuals had ever been observed, produced only blue offspring, 16 in three litters. When the F_1 blues were backcrossed to fawn, there were produced in ten litters a total of 42 blue and 46 fawn young, a 1:1 ratio. This result suggested that fawn was probably an allele of blue dilution, to which it behaved as a recessive. But this interpretation was straightway disproved.

A fawn male mated to a black female produced a litter of six intensely black young, the same result qualitatively as would result from a cross of blue with black. A backcross of F_1 black to fawn was expected to produce two types of young, black and fawn respectively, in a 1:1 ratio, if fawn is an allele of blue. But instead the backcross produced four types of young in a 1:1:1:1 ratio. Obviously therefore the fawn phenotype



FROM BLACK TO BLUE FAWN

Figure 12

Two different dilution genes are involved in this progressive series of decreasing pigmentation. The black animal (left) is heterozygous for both blue and fawn (*DdFf*). Next to it is the black fawn (*Ddff*) type, then blue (*ddFf*), and at the right, the homozygous recessive blue fawn (*ddff*).

differs from black by two independent recessive genes. One of these is the well known gene of blue dilution, *d*; the other is what we shall henceforth call the fawn gene, *f*, a new and independent type of dilution.

The four phenotypes which were produced by the backcross of F_1 black to fawn are shown side by side in Figure 12. They are, in order from left to right, black, black fawn, blue and blue fawn. Qualitatively the picture is unsatisfactory because it shows only the relative intensity of the pigmentation of the animals, not their color differences. In reality the colors are respectively black, coffee brown, blue and lavender. Numerically they are at this writing black 15, black fawn 13, blue 9, and blue fawn 12, which result shows independent recombination of *d* and *f*, within the limits of probable error.

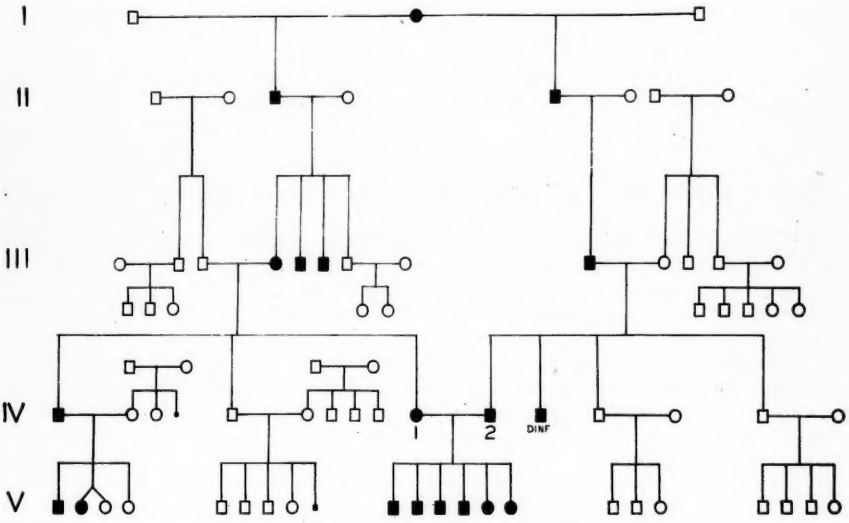
The original fawn individuals must have been homozygous for blue dilution, *d*, since the race in which they made their appearance was homozygous for that gene. They were also homozygous for a new dilution gene, *f*, which reduces the pigmentation of both black and blue. In terms of the two dilution genes, the four backcross phenotypes of Figure 12 are *DdFf*, black; *Ddff*, black fawn; *ddFf*, blue; and *ddff*, blue fawn.

A further study of the linkage relations of the fawn gene is being made, the result of which will be reported later.

UNILATERAL HEXADACTYLY IN MAN

LESTER A. BARRER

Biological Laboratories, Harvard University



SIX FINGERS THROUGH FIVE GENERATIONS

Figure 13

Hexadactyly of the left hand only has been transmitted through five generations of this Belgian family. Consistently, the condition expresses itself in an extra fifth finger of the left hand, neither the feet nor the right hand being affected in any visible way. The condition appears to be identical in both the heterozygous and the homozygous state.

WHILE bilateral hexadactyly is not uncommon in man, unilateral hexadactyly is quite rare. The pedigree presented here is of additional interest because it contains one family where both parents and all of their offspring display the trait. (See Figure 13.)

Most of the subjects of this pedigree live in several small towns in the Ardennes Woods in Belgium.* All affected members show the same expression of the character. Each one had an extra fifth finger on the left hand. The extra finger, containing three bones and a normal fingernail, was about a half-inch shorter than the normal small finger of the individual. In no instance was there any sign of polydactyly of the right hand, polydactyly or syndactyly of the feet, or any other abnormality of the extra finger.

Although it is generally accepted that bilateral hexadactyly is due to the action of a single dominant gene, very little is known about the genetics of the unilateral condition. From this pedigree, however, it seems justifiable to conclude tentatively that unilateral hexadactyly is either a case of complete dominance, or, at least, of dominance with a very high degree of penetrance. Here, wherever one of the parents was hexadactyl, one

*This pedigree was obtained by the author from personal interviews with various members of the entire family. In no case was any individual classified solely upon the statement of one individual; two members of the family must have personally seen the sixth finger on the individual in question. Out of the 19 cases of unilateral hexadactyly in this pedigree, the author personally examined 13 cases including IV-1 and IV-2 and all their offspring.

or more of the offspring would be hexadactyl; and when both parents (IV-1 and IV-2) were hexadactyl, all the children were hexadactyl.

Since this last instance was the union of two heterozygotes, the probability is great that one or more of these children is homozygous for unilateral hexadactyly. According to the laws of segregation and the laws of chance, there are 91 chances out of 100 that at least one of these individuals is homozgous, and only 9 chances out of 100 that all of these children are heterozygous. Thus, with such a good chance that one of these individuals is homozygous, it seems reasonable to assume that the homozygous expression of unilateral hexadactyly is of the same degree as the heterozygous form.

✦

THE CHEMISTRY AND BIOLOGY OF NUCLEIC ACID

AN examination of the nineteen papers that constitute the published report of the Symposia of the Society for Experimental Biology* held at Cambridge, England, in July, 1945, might well lead one to the conclusion that in biological fields everyone is interested in nucleic acids but that no one knows much about them. This volume carries one from the hard-boiled chemical realism of Gulland's paper, in which it would seem that all we know about nucleic acids is that they are built up of nucleotides, to the refreshing abandon of Darlington, who emphasizes that if we are to understand the role of the nucleic acids in cellular processes and in general rewrite cytology in chemical terms "we must be prepared to embrace and reject hypotheses with appropriate recklessness."

As to the biological importance of nucleic acids there can be no slightest doubt. The circumstantial evidence pointing to them as essential components of chromosomes and genes is extensive. The ribonucleic-desoxyribonucleic acid relation is correlated with the nuclear cycle, while the presence of large amounts of ribonucleic acid in the cytoplasm appears to be closely associated with protein synthesis. The newer work on bacterial transforming principles makes it clear that a high degree of biological specificity resides in the nucleic acids.

While many directions have been clearly pointed out in which further advances in our understanding of the chemistry and biology of nucleic acids will be made, it seems evident that these advances will require a tremendous amount of painstaking experimental work. In summing up the techniques now available with which nucleic acid cytochemistry can be investigated Danielli says, "the Feulgen technique holds out such great promise that one is tempted to throw overboard one's remaining reservations about it; temptation notwithstanding, this may not be done. The use of enzymes has hazards so great that it is highly improbable that it can ever be raised above the status of confirmatory technique, and even this hope may prove to be illusory. The use of diazonium hydroxides is very promising but needs drastic overhauling. The ultraviolet absorption technique likewise needs drastic overhauling from the strictly chemical point of view."

Nucleic Acid is a book that should be available in every biological library. Its content makes up an essential part of the lore of modern cytology, genetics, biochemistry, physiology, and bacteriology. It impinges on almost every branch of modern biological science.

G. W. BEADLE

Kerchoff Laboratories of Biology
California Institute of Technology

*DANIELLI, J. F., and B. BROWN (Editors); *Nucleic Acid,* Symposia Soc. Exp. Biol. (British) Number 1, pp. 1-290, Cambridge, at the University Press; New York, The Macmillan Company, 1947. $8.50.

GENETICS OF SESAME

D. G. LANGHAM

V. Some Morphological Differences of the Sesame Flower (*S. indicum* L.)

IN a previous paper[8] in which color differences in sesame flowers were discussed it was pointed out that many structural differences also existed. These are too numerous to describe in detail, but their principal characteristics will be the subject of the present paper.

Material for this study consists of 35 varieties of sesame with numerous hybrids between many of them. The offspring of crosses of varieties from widely separated geographical regions have expressed many characters not found in either parental phenotype. The expression of some other characters was changed by transferring the genes responsible for them to other genotypes. The study of this wealth of material has been extremely useful in preparing a linkage map for sesame and also in explaining certain cases of sterility and semi-sterility among varieties.

Description of Characters

The extreme variation in the sesame flower revealed by an intensive study of different varieties makes the selection of a typical flower difficult. The most frequently appearing type is shown in Figure 14*A* and is described in Bailey's *Cyclopedia*[1].

Some of the variations of this typical flower as seen in our breeding plots are described below:

1. *Foveola vs. absence of foveola.*—The typical sesame flower has a small V-shaped pit in the petal, which forms the base of the floral tube. Neither the origin nor the purpose of this small indentation is known at this time, but it is useful in a genetical study of the flower because of its relation to color distribution and to certain morphological characters. A few plants without this foveola occurred and have been selectively bred to give pure lines.

2. *Internal pubescence vs. its absence.*—Near the foveola of some varieties is found a small brush of plant hairs; these are absent in other varieties. The number of hairs varies from one to approximately 50 per flower, but the number for any given variety is relatively constant. The ease of classification of this character in segregating populations made possible the determination of seven different qualitative factors for the presence or absence of hair. Second generation ratios of 3:1, 9:7, 13:3, 15:1, 1:3, 7:9 and 1:15 have been confirmed by F_3 and F_4 populations.

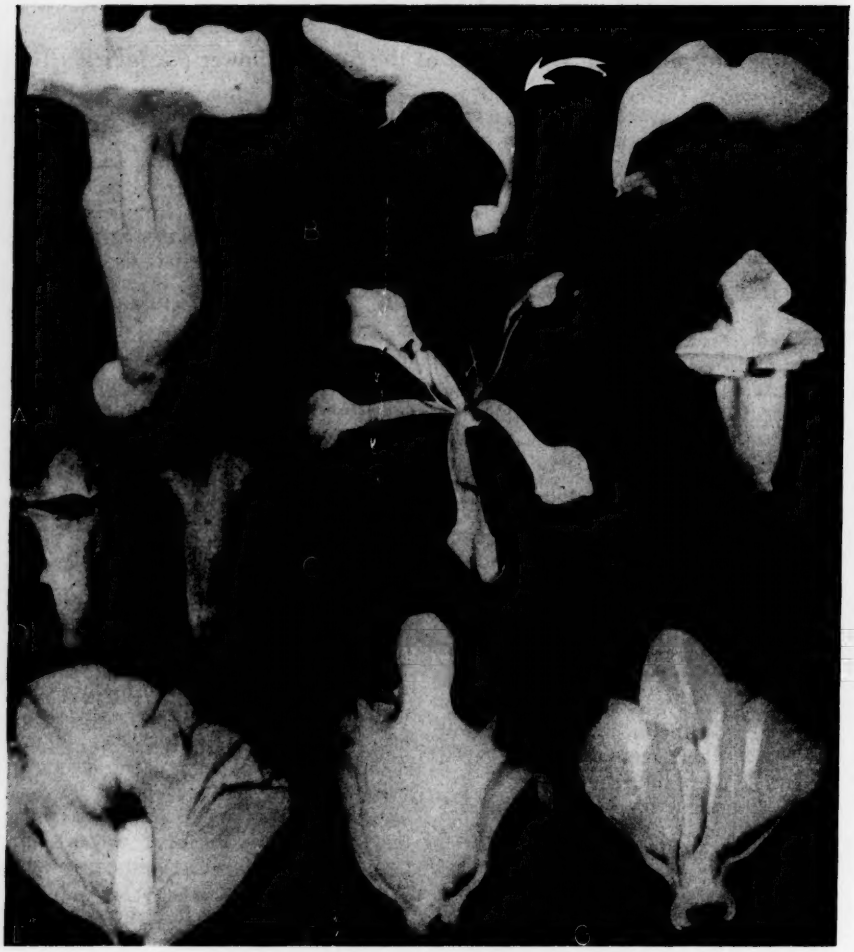
3. *Tubular flower vs. split flower.*—In contrast to the usual tubular flower, a type with five petals completely separated has been isolated. It is structurally sterile because the absence of the tube permits the style to curve upwards thereby separating the stigma from the anthers. Application of pollen, however, results in seed set. In the F_2 progenies studied, recessive duplicate genes have been found responsible for "star" flower.

Other types of split flower occur in which the tube may be opened by division of the two dorsal petals, or along one side, or near the base. All of these types have been isolated in pure lines. Segregations of normal to split flower recorded in different F_2 generations are 3:1, 9:7, 1:3.

4. *Open flower vs. closed flower.*—Ordinarily about seven o'clock in the morning, the lip of the lower petal of the flower bends downwards, leaving an opening in the floral tube. Some lines have been isolated in which the tube remains closed. There are three different types of closed flowers:

A. Lip normal, but remains closed.

B. One half of flower tube, including lip, remains green instead of becoming violet in color.



FLOWER MORPHOLOGY

Figure 14

A—"Normal" sesame flowers on day of opening. The curvature in the center of the vertical portion of the flower tube is the U-shaped foveolar indentation. *B*—Portion of flower with the dorsal part of corolla removed, showing tuft of flat hair near foveola as compared with absence of this hair. *C*—"Star" flower, with petals separated. *D*—Extra enations on exterior of the corolla, a characteristic associated with non-shattering seed capsules. *E*—Flower with fused stamens, as compared with normal flower (*F*), and flower with extra tissue on inside of corolla (*G*).

C. Tips of petals become necrotic the day the flower should normally open.

A and C are recessive and B are dominant in F_1 hybrids with normal flowered types. The F_2 generations have not yet been studied.

5. *Extra enations on the exterior of the corolla tube vs. wild type.*—Flowers with these extra growths have been isolated three times and in each case the plant differed from the others in that the seed capsules were indehiscent in contrast to ordinary sesame. This valuable mutant form behaves as a simple recessive.[5]

6. *Extra tissues on the inside of the sesame flower vs. wild type.*—Ordinarily the five petals are smoothly joined to form the corolla tube; the borders of adjacent petals unite edge to edge. A new type of flower in which adjacent petals, particularly the lower ones, double inward and unite with extra tissues on the inside of the tube, has been isolated in a pure line.

7. *Fused filaments vs. separate filaments.*—Usually the filaments are completely separated one from another, but new lines have been obtained by selection among hybrids in which several or all of the filaments are fused. This type is recessive to the normal.

8. *Flattened vs. curled lip.*—A type of flower in which the lip curls downwards instead of remaining straight, occurred in a variety from Brazil. It is recessive in F_1 generations and difficult to classify in F_2.

9. *"Rough" foveola vs "smooth".*—By looking in profile at the foveola of some varieties, the elongated cells in the pit of the foveola have a brush-like appearance, while in others the surface is smooth. In crosses between the two types smooth is dominant and segregates as a simple Mendelian factor.

10. *Defective foveola vs. normal foveola.*—In some segregating populations individual flowers occurred in which the foveola does not form a complete U, but rather a portion of it, or a split U. Seeds from these plants give progeny with similar type flowers. In crosses between this and ordinary flowers the complete U dominates in F_1 generation and classification is difficult in the second generation, although the defective types occur in approximately 25 per cent of the progeny.

11. *Single vs. double lip.*—Selections in which the majority of the flowers have an extra petal in the base, giving two lips and usually two foveoli, have been made in segregating populations of certain hybrids.

12. *Single vs. multiple flowers.*—Selections have been made in which double flowers occur frequently. The flowers may be nearly separated, or fused at different angles. Triple and other multiple forms occur in these same lines.

13. *Large, normal, and small flowers.*—The average flower is approximately two and one-half centimeters long and one centimeter in diameter. But flowers three and one-half centimeters and others one centimeter long with a corresponding variation in diameter have been isolated. The size of the flower segregates as a multiple factor character in hybrids.

14. *Thick, normal, and thin petals.*—The flowers of some varieties are so thinwalled that they become soaked by a heavy dew, while others are so thick they are quite firm to the touch. The most common flower type is between these two extremes.

15. *Wide, normal, and narrow foveola.*—In the study of color distribution in the sesame flower, a wide foveola is desired because the limits of the different pattern factors are more easily determined than in narrow types. Individual plants in which flowers with a broad foveola were obtained in a variety from China. The narrow type occurs in a variety from Nicaragua.

16. *Reduced lip of the petal vs. normal lips.*—In a variety from Brazil certain types were isolated in which the tips of petals were shortened and the lip hardly existed. In this type natural

crosses are reduced because the bees cannot find a resting place to enter the flower. Reduced petal segregates as a simple recessive in F_2 generation.

Discussion

The morphological differences in the sesame flower described in this article occurred in breeding plots in which many varieties, hybrids and selections were under study for commercial use. The importance of flower type in the percentage of natural cross-pollination, dehiscence of seed pod, relative fertility and other factors demonstrate the need of a detailed study of genetics of flower type in order to facilitate plant breeding with this crop. The results presented were obtained from a study of approximately fifteen thousand segregating populations.

Summary

1. Brief description of some morphological differences occurring in the sesame flower are given.

2. The relation of the differences to the sesame breeding program are discussed.

VI. Some Genetic Variations in Plant Color in Sesame

THIS is a preliminary report of a study on inheritance of color differences in the sesame plant. Some of these plant characters are related to flower color and to seed color. The complete relationship between foliage, flower, and seed will be discussed in a future article.

Seedling Colors

1. *Albino seedlings.* — For the past six years a few albino seedlings have been observed in commercial plantings, but it was impossible to isolate this character without testing thousands of plants in an effort to find the heterozygous form. This year, however, one line from an individual plant selection segregated green and white seedlings in the ratio of 3:1, and a heterozygous strain is now available.

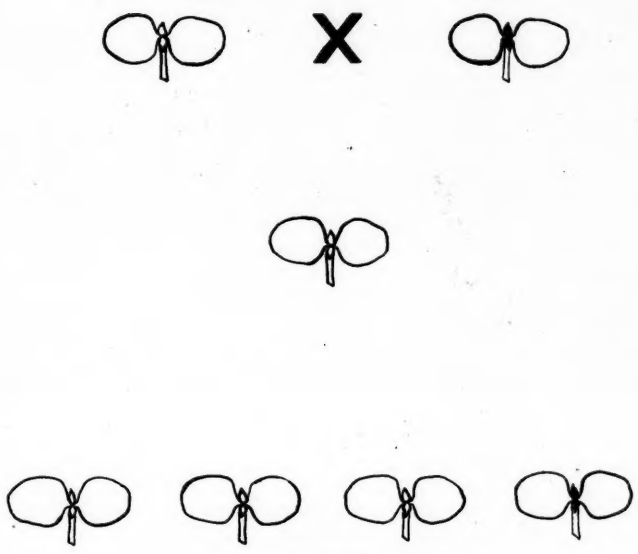
2. *Virescent seedlings.*—In spite of the fact that sesame is approximately 96 per cent self pollinated[2,3], virescent seedlings are found frequently. Those observed in our breeding plots are simple recessives and three have been demonstrated to be genetically distinct.

3. *Pale yellow.* — There is extreme variation in the degree of color in sesame plants, ranging from pale yellow to dark green. One of the yellow types segregates as a simple recessive but the others are difficult to classify in segregating populations due to intermediate grades.

4. *Purple, green, and yellow leaf tips.* —When the tips of the first pair of true leaves are barely visible between the cotyledons, they may be purple, green, or yellow. Both the purple and the yellow change within a day or so to green and the classification must be made at the proper time. In all cases studied to date, purple dominates green or yellow. Two types of purple have been observed: one which is independent of whether the plant germinates in the sun or in the shade and another which germinates green in the shade and purple in the sunlight. These are complementary dominant genes and one is linked with a virescent. Classification is simple.

Among many F_2 progenies from numerous crosses, green leaf tip dominates yellow in some cases, and yellow is dominant in others. Two complementary dominants have been isolated for green leaf tip (yellow leaf tip being recessive in these cases). Yellow leaf tip segregates as a simple dominant in certain other crosses.

5. *Purple stem.*—The color of the seedling stalk immediately below the cotyledons may be purple or green. Purple stem is dominant to green and segregates sharply in the F_2 generation. Seedlings with the combination of purple leaf tip and purple stems, green leaf tips and green stems, purple tip and green stems, have been found, but the combination of



COLORED LEAF TIPS

Figure 15

The tips of the first pair of true leaves may be purple, green, or yellow as they emerge between the cotyledons. Later the purple and yellow varieties turn green, so that the character can only be recognized during a brief period.

green tips and purple stems has not yet been recorded.

Plant Colors

6. *Purple stems and leaf petioles.*—Two types of purple have been encountered:

a. Develops in the shade or in the sunlight. Determined by a simple dominant gene.
b. Develops only in the sunlight. Dominant complementary genes differentiate this purple from green.

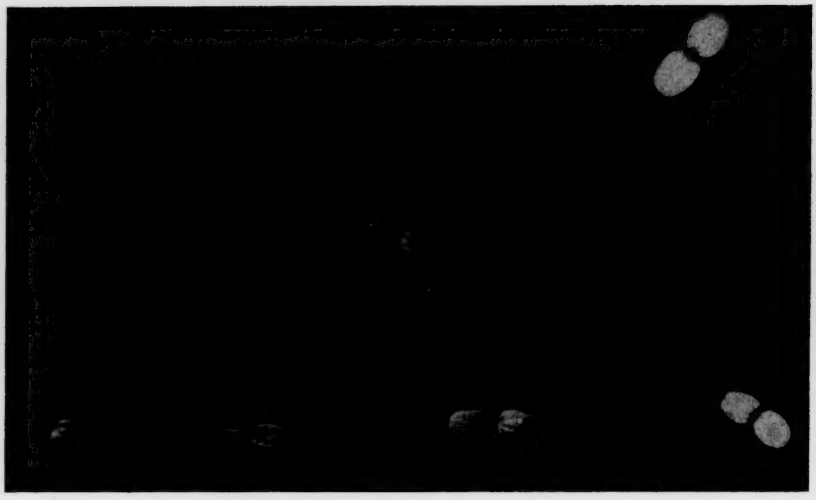
All of these genes for purple are essential for the expression of the flower color known as flake.[8]

7. *Bronze stem and leaf petioles.*—This color is usually faint and is visible only in the young leaves and stems of the nearly mature plants. It is determined by a simple dominant.

8. *Dotted stem and leaf petioles.*—This type in which the color is localized in dots, occurred in a variety from Brazil and in our Selection No. 5. It is recessive to green stem and also to purple and bronze.

9. *Green stem and leaf petiole.*—As can be seen from the above discussion green acts as a recessive to purple and bronze, and as a dominant to dotted stem. The combination of the flower color known as *flake* and green stem has not yet been found; but the flower color *smear* occurs in combination with green stem and bronze stem, but not in purple or dotted.

10. *Mottled leaf.* — This character was described in a previous paper[4] and consists of yellow blotches in the green leaves of nearly mature plants. It is a simple recessive.



GREEN AND YELLOW COTYLEDONS

Figure 16

Green and virescent cotyledons represent an allelic pair, with green dominant. In F_2 a 3:1 segregation of green and yellow is observed.

Discussion

Most of the seedling and plant colors described in this paper can be easily classified in segregating populations, if care is taken to make the observation at the proper stage of growth and under favorable conditions of light. Purple leaf tips, for example, are visible just as they emerge between the two cotyledons, but a day or so later they cannot be distinguished from green. Bronze stems may be confused with green stems unless classification is made in the *later* development of the plant. If proper care is exercised in classification, all these characters are useful in a genetical study of sesame. They are particularly valuable in reference to flower and seed color. A complete discussion of the relations of the three will be made at a future date.

Summary

1. Brief descriptions of seven seedling colors and five plant colors are given.
2. The mode of inheritance of most of these is discussed.
3. The importance of the time factor in making classification is emphasized.

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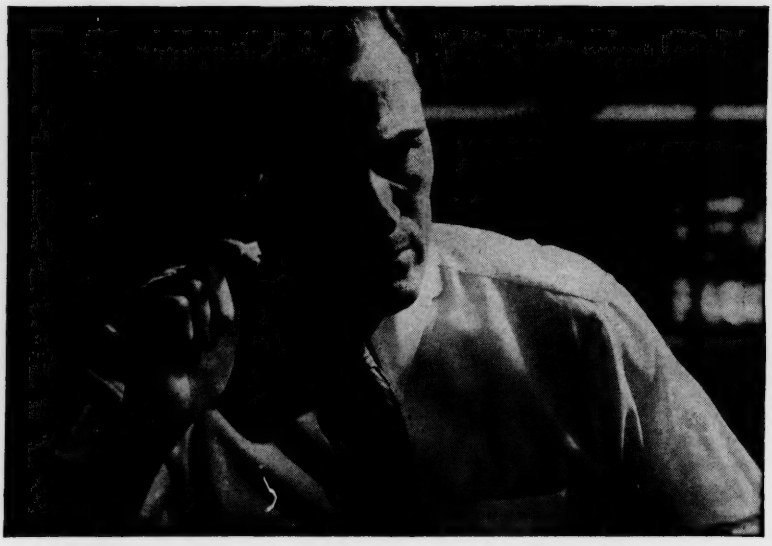

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